# Sediment Impact Assessment Model (SIAM)

David M. Mooney[1], David S. Biedenharn[2], and Chester C. Watson[3]

[1] Graduate Research Assistant, Colorado State University, Engineering Research Center, Fort Collins, CO 80523, 970-491-8999, davemoon@lamar.colostate.edu.
[2] Engineer, U.S. Army Corps of Engineers, Engineer Research Development Center, 3909 Halls Ferry Road, Vicksburg, MS 39180, 601-634-4653, David.S.Biedenharn @erdc.usace.army.mil
[3] Professor, Colorado State University, Engineering Research Center, Fort Collins, CO 80523, 970-491-8313, cwatson@engr.colostate.edu.

**Abstract**

A rapid assessment sediment transport tool is currently being developed at the Engineer Research Development Center (ERDC) that will allow for evaluation of numerous sediment management alternatives relatively quickly. The Sediment Impact Assessment Model (SIAM) provides a framework for combining watershed sediment sources, channel morphological, hydrologic, and hydraulic information in a series of reaches representing a network of channels. The algorithms use the connectivity between reaches to evaluate the sediment impact from local changes on the system from a sediment continuity perspective. The results map potential imbalances and instabilities in a channel network and provide the ability to assess the impacts of existing sediment sources such as bed and bank erosion, gullies, gravel mines, and surface erosion from the watershed, as well as the response to modifications such as bank stabilization, grade control structures, flow control (dams, stormwater management, etc.), land treatments, urbanization, land use changes, and other activities that modify the water and sediment supply to the channel system.

## 1. Introduction

As water resource projects become more and more complex, there is a growing emphasis on the ability to implement effective regional sediment management. A common goal of many regional sediment management projects is the reduction of sediment loading from the watershed. This is usually accomplished by rehabilitation features such as grade control, bank stabilization, drop pipes, dams, and land treatments. While these features are often implemented to reduce sediment yields to downstream reservoirs, flood control channels, or wetlands, the spatial and temporal response of these features are complex, and often result in unanticipated morphologic changes in the channel system. Therefore, the challenge in regional sediment management projects is to select the appropriate sediment management features that produce the desired reductions in sediment delivery while minimizing the disruption to the stability of the channel systems. In order to facilitate this decision process, ERDC is currently developing a Sediment Impact Assessment Model (SIAM), which provides for the rapid assessment of the impacts of sediment management features on downstream sedimentation trends. A brief overview of the SIAM is described below.

## 2. SIAM Overview

The SIAM provides a framework to combine channel morphological, hydrologic, and hydraulic information for a series of reaches representing a network of channels. The algorithms use sediment continuity and the connectivity between reaches to evaluate the impact from local changes on the system. The SIAM develops a map of potential imbalances in a channel network to provide the first step in identifying design or remediation needs.

The SIAM provides the ability to assess both short- and long-term responses to changes in the watershed. The short-term impacts reflect the changes in the supply of wash load sized material, while the long-term morphologic adjustments are based on the changes in the supply of bed material. The wash load-bed material load threshold is supplied by the user for each reach of the channel system.

For each reach in the channel network, the SIAM creates a sediment budget by summing the supply from local sediment sources, estimating the annual transport capacity for bed material classes, and determining the contribution in wash load material size classes. For each reach, the results show the total contribution from local sediment sources, the annual transport capacity, wash load supply, and bed material supply.

### 2.1. Annual Transport Capacity

The annual transport capacity reports the quantity of bed material the stream can move over a year. Annual transport capacity applies to bed material classes. Current routines apply Yang's transport relationship (Yang 1973) to each discharge in the hydrology records. Future versions will include additional transport functions that will reflect a wider range of sediment sizes. The procedure first assumes a uniform material, and then adjusts by the fraction present in the reach (Yang 1996). Multiplying by the duration of the discharge yields the total load moved in a flow record. The annual load sums the contribution from each hydrology record. A program developed by Stevens and Yang (1989) to match sediment concentrations was used to verify these computations.

### 2.2. Reach to Reach Sediment Connectivity

To determine the wash load material supply and bed material supply, the program compares the transport mode in the reach to the transport mode in the supplying reaches immediately upstream. Four possible transition scenarios can occur:

1. The grain size moves as wash load locally and was wash load upstream;
2. The grain size moves as wash load locally but was bed material load upstream;
3. The grain size moves as bed material load locally but was wash load upstream; and
4. The grain size moves as bed material load locally and upstream.

The supply sums contributions from local sources and upstream reaches. At junctions of two or more streams, scenarios 1 and 2, or 3 and 4 may occur simultaneously in a grain-size class. Sources are not double counted. Irrespective of transitions, the sum of the wash load and bed material supply equals the total material entering the reach.

### 2.3. Wash Load Material Supply

The wash load material supply includes grain classes at or below the wash load threshold from both local sources and reaches immediately upstream. The wash load material supply also includes sediment that transitioned from wash load in an upstream supply reach to bed material in the current reach. Figure 1 shows the program logic for determining the wash load material supply.

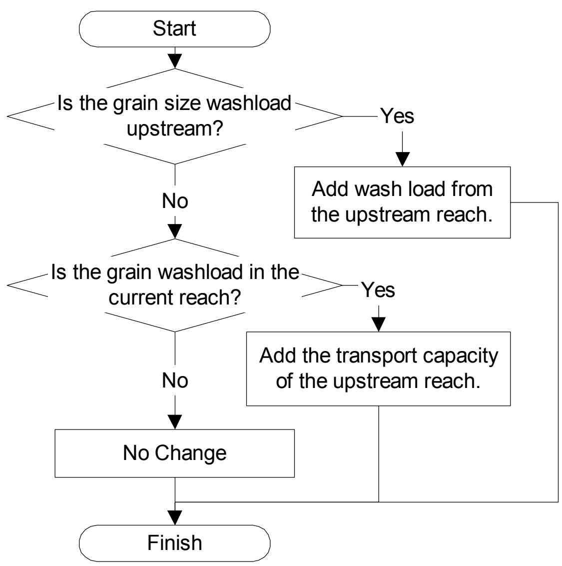


**Figure 1.** Wash Load Material Supply Logic

If the grain size moves as wash load upstream, the program adds the upstream load regardless of transport mode in the present reach. If the sediment was bed material in the upstream reach, but is wash load in the current reach, the upstream transport capacity is added to the supply. If the sediment was bed material in the upstream reach and is still bed material in the current reach, there is no wash load supply.

## 2.4. Bed Material Supply

The bed material supply includes only grain classes moving as bed material load in the current reach regardless of the transport mode upstream. Figure 2 shows the logic to determine the bed material supply.

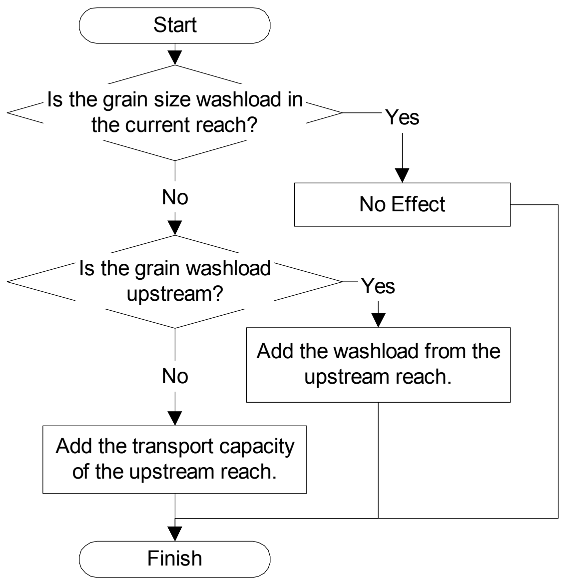


**Figure 2.** Bed Material Supply Logic

If the grain size moves as wash load locally, the bed material supply will neglect the grain-size class regardless of upstream transport mode. If the grain size was wash load upstream, the program adds the amount to the bed material supply. If the grain size was bed material load upstream, the program adds the transport capacity of the upstream reach to the bed material supply. In the case of a supply-limited stream, finer particles not present in the bed armor layer will be considered wash load material. All particles are wash load material over bedrock. Bed material supply includes local sources.

# 3. Input Description

The SIAM process requires developing input records describing the bed material, hydrology, hydraulics, and local sediment sources. By separating input development from synthesis, the model provides flexibility to vary techniques and procedures.

## 3.1. Grain-size Class Records

The grain-size classes divide all sediment gradations within the model into bins represented by a single diameter. The table of size class records applies to the entire model, providing a global template for performing grain-specific computations. Users specify the number of bins to match the anticipated resolution required for the project. Altering the grain-size classes after initial creation requires updating the tables for bed material records and the sediment sources.

### 3.2. Sediment Reaches and Network Topology

The SIAM treats a network of streams as a series of sediment reaches. A sediment reach divides a channel network into segments at significant changes in bed material, hydrology, hydraulics, or sediment sources. Sections upstream and downstream of a tributary junction must belong to separate reaches. Additional reaches span the length of potential projects or portions of a river with unique characteristics. Topology is defined by specifying the reach immediately downstream.

Users specify the characteristics of a stream network in six tables: bed material, sediment properties, hydrology, hydraulics, sediment sources, and loading templates. Each table stores data as a series of records grouped into named sets. Tables function independently of each other and the network of sediment reaches. Figure 3 shows a reach associated with a set of records from the different tables. Specifying local sediment sources requires two tables, one for loading templates and another for the location and quantity of each source.

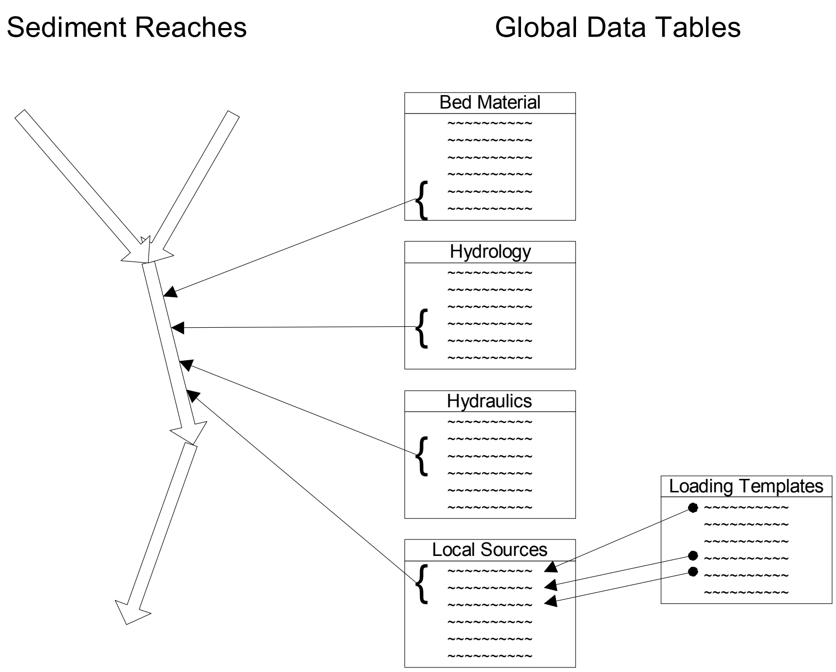


**Figure 3.** Sets of Records Associated with a Sediment Reach

The same set of tables may apply to multiple reaches, allowing reusable collections of values rather than duplicating data entry. Modifications to a record apply to all reaches associated with the set. A record can only belong to one set. The following sections describe each table. The fields in the network table include:

- **Name**: text identifier for the reach
- **Stream**: name of the stream
- **Downstream Reach**: name of the stream and reach immediately downstream from the element
- **Bed Material**: name of the set containing bed material records for the reach
- **Sediment Properties**: name of the record describing properties of the sediment including the wash load threshold
- **Hydraulics**: name of the set describing the hydraulic performance of the reach
- **Hydrology**: name of the set specifying the flow duration curve for the reach
- **Local Sediment Sources**: name of the set identifying sediment inputs
- **Bed Slope**: profile slope of the channel bed
- **Comment**: text notes for the reach

### 3.2.1. Bed Material Records

The bed material table specifies the decimal fraction of sediment present for each grain-size class in the size class records. The values can not exceed unity, but the model will accept smaller sums to allow scenarios where a user wishes to exclude fractions from the model. Order does not affect computations. If no record is entered for a particular grain-size class, the model assumes none is present.

### 3.2.2. Sediment Property Records

A sediment property record contains the diameter of the largest material moving as wash load through a reach. Future versions may use sediment property records to define parameters required for scour and deposition of cohesive material.

### 3.2.3. Hydrology Records

Hydrology records define an annual flow duration curve by a series of discharges and the corresponding decimal number of days that the flow occurs. The sum of the duration fields within a set of records should not exceed an average year, 365.25 days. The model accepts smaller sums to allow scenarios where the user wishes to exclude discharges of negligible impact. Order does not affect computations.

### 3.2.4. Hydraulic Records

Sets of hydraulic records describe the flow properties of the channel over a range of discharges. Sediment transport computations estimate the hydraulic performance of each hydrology record using a discharge-based rating curve. Equilibrium computations use the records to estimate a depth-based rating curve. Hydraulic records should bracket the range of discharges in the hydrology records for the reach. To minimize the number of backwater runs required to define channel hydraulics, discharges in the hydraulic records do not need to match discharges in the hydrology table. In transport capacity computations, intermediate values are estimated by a linear transformed log interpolation between the nearest points. Values outside the range interpolate from the nearest two points and generate a warning. Equilibrium computations fit a power function to the depth-area and depth-hydraulic radius relationships using least squares regression.

### 3.2.5. Local Sediment Sources and Sediment Loading Records

Local sediment sources include all material supplied to a reach from sources outside of the channel bed or upstream of the model boundary. Sources include inflows to the most upstream reaches, bank failure, surface erosion, gravel mining, gully formation, and any other production. Sediment sources do not include material hydraulically transferred between modeled reaches. Specifying a sediment source requires a set of records in two tables. The local sediment source set is associated with a reach and specifies the annual quantity of sediment supplied by records in the sediment loading table. Table 1 shows the table for local sediment sources.

**Table 1.** Local Sediment Source Record Fields

| Name | Multiplier | Loading | Comment |
|---|---|---|---|
| ⋮ | ⋮ | ⋮ | ⋮ |

The loading table contains a field for each grain-size class in the global template. Table 2 shows the headings for a loading table.

**Table 2.** Sediment Loading Record Fields

| Name | Class 1 | Class 2 | Class … | Class n | Comment |
|---|---|---|---|---|---|
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

The two-table method allows the user to define generic load values and then apply the source to any reach. The multiplier scales loads based on the magnitude or number of sources contributing to a reach. Each record in the loading table must have a unique name. Users must ensure units of the loading record and the multiplier result in mass per year.

Order does not affect computations. Some anticipated loading-multiplier pairings include:

- **Upstream Boundary Sediment Load**: discharge and duration
- **Gully Supply Rate**: number of contributing gullies
- **Bank Failure Block**: length of bank within the reach
- **Surface Erosion Rate**: drainage area

## 4. Output Description

For each reach and each grain-size class the output table displays the total supply from sediment sources, upstream hydraulic wash load material, upstream hydraulic bed material, and the transport capacity. Table 3 shows the format.

**Table 3.** Format of an Output Table

| Stream | Reach | Sediment Sources Supply | | | Transport Capacity | | | Wash Material Supply | | | Bed Material Supply | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Class 1 | Class 2 | … | Class 1 | Class 2 | … | Class 1 | Class 2 | … | Class 1 | Class 2 | … |
| Stream 1 | Reach 1 | | | | | | | | | | | | |
| | Reach 2 | | | | | | | | | | | | |
| | ⋮ | | | | | | | | | | | | |
| Stream 2 | Reach 1 | | | | | | | | | | | | |
| | Reach 2 | | | | | | | | | | | | |
| | ⋮ | | | | | | | | | | | | |
| ⋮ | ⋮ | | | | | | | | | | | | |

Output from the SIAM can be summarized in both tabular and graphical format. In tabular format, an "answer quit" provides the ability to view the stability of multiple scenarios simultaneously over all reaches. A quilt displays scenarios in the columns and the reaches in rows with the equilibrium parameter filling in the matrix. Color-coding identifies significant trends. Bar and scatter charts focus on specific streams or reaches to show more detailed observations. A typical plot covers a single reach or a single stream. The chart may show data for any combination of the output variables including summations over all classes or differences between parameters.

## 5. Summary

The SIAM aims to integrate watershed-scale sediment continuity concepts into stream rehabilitation and management. The analysis will provide an intermediate step between qualitative evaluations and a mobile boundary numerical model. The SIAM provides a framework to combine hydrology, hydraulics, and sediment supply into a geomorphic assessment and rehabilitation design. With sediment as the number one ranking pollutant in streams and a contributing agent in many others, the addition of the SIAM into the river-engineering toolkit will empower designers and planners to more easily consider sediment supply and transport in management and rehabilitation of channel systems. The SIAM is currently under development with initial tests on a demonstration watershed in northern Mississippi. Plans for FY 03 include application to the Hickahala and Yalobusha Watersheds in Mississippi, and the Judy's Branch Watershed in Illinois. Other watersheds are also being considered as part of reimbursable activities.

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